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Dynamic Analysis of Air Conditioner Compressor Mounting Bracket

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ABSTRACT

Simulation plays very important role in the Automotive industries for the higher levels of quality, better cost effectiveness and quick market response. In this paper, the use of dynamics analysis technique is used for the simulation of the compressor mounting bracket for various vibration loads. The standard testing conditions were used for the testing of the compressor mounting bracket . The results showed that resonance in the dynamic analysis is the major cause for the failure of the compressor mounting bracket , under static analysis, under the same magnitude of load resonance cannot be predicted . Thus, dynamic analysis gives a best results for design validation of the compressor mounting bracket
***Keywords*— Air Conditioner Compressor mounting bracket, Dynamic analysis, Mode shapes, Resonance, Topology Optimization**

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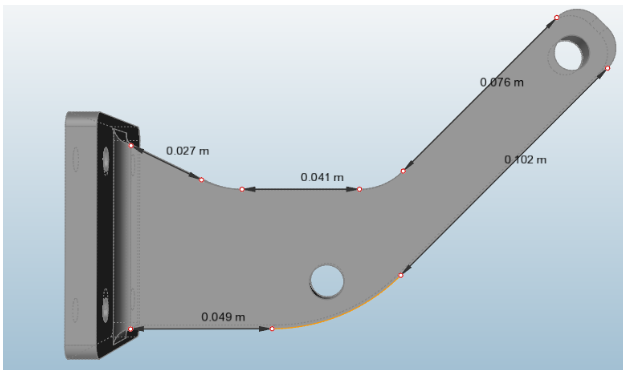
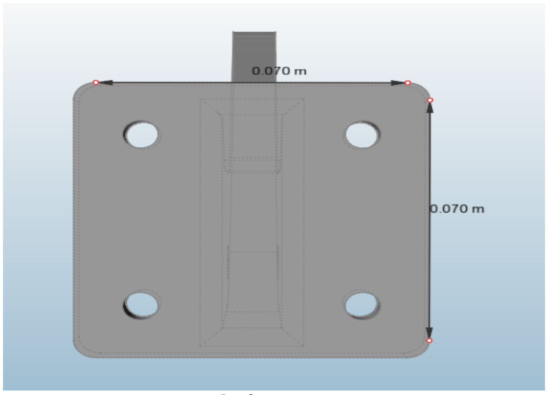
I. Introduction

The compressor plays a very important role in the automotive air conditioning system. The unbalanced forces produced from the engine and compressor causes the structure vibrations. The compressor is supported by the engine mounting to reduce the vibratory forces is called compressor mounting bracket.



(a) Right Hand Side View

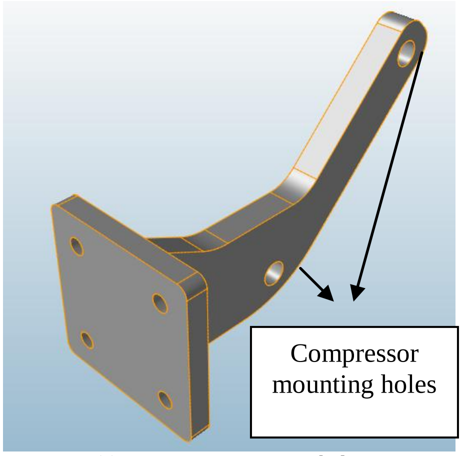


(b) front view

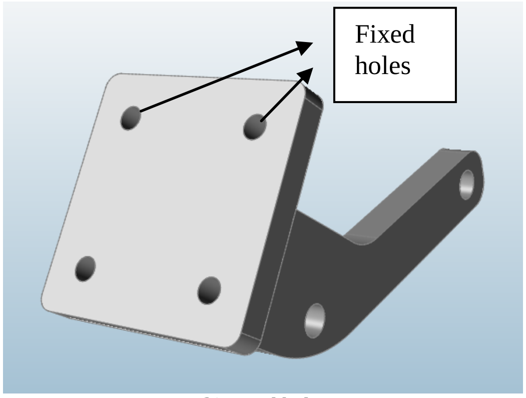
Fig. 1 (a), (b). Detailed Drawings of the Compressor Mounting Bracket

II. CAD Model

From the reverse engineered data, the component is modeled in commercially available modeling software. The generated CAD model is shown in Fig.2



(a) Compressor mounting holes



(b) Fixed holes
Fig 2. CAD MODEL

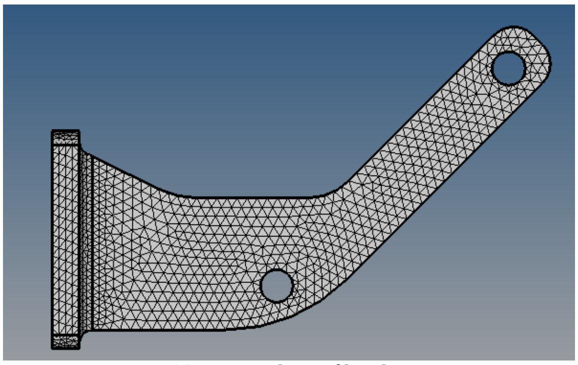
III. Mesh Generation

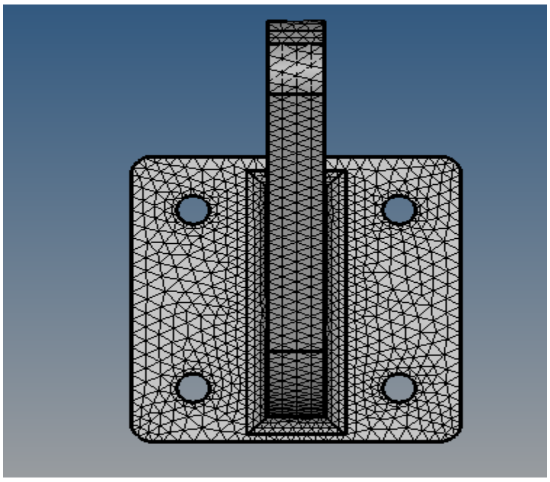
Tetrahedral elements are used for meshing. Meshing of the compressor mounting bracket has been done according to the geometry.

A. Quality Checks for Tetra Meshing

- Tetrameshing
- Average Element Length : 3mm
- Min.Length :Based on feature
- Aspect Ratio : 5
- Skew : 45
- Minimum Tria. Angle : 20
- Maximum Tria. Angle : 120
- Jacobian : +ve
- Tetra Collapse : 0.3

Holes to be meshed with even no. of elements and also put 1 layer of washer elements around holes.


(a) Tetrameshing of bracket


(b) Tetrameshing of bracket
Fig 3 (a),(b). Meshing

IV. DYNAMIC ANALYSIS

Dynamic analysis for the compressor mounting bracket include two steps:

- Normal modes analysis.
- Modal frequency response analysis.

Both steps are related to each other. Input parameter of the second step is taken from the output of the first step.

A. Need of normal mode Analysis

1) For automotive components like engine mounting bracket or chassis mounting bracket, normal mode analysis plays the major role for the design approval.
2) Resonance is produced when natural frequency becomes equal to the external frequency. Resonance as very high amplitude of vibration builds up causes component to fail.

B. Conditions for the normal mode Analysis

Following conditions are applied for the normal modes analysis:
1) External forces is not applied as per the condition for the natural frequency analysis.
2) *Constraints*- Natural frequency analysis is carried out as per actual constraint.
3) *Damping*- It is neglected for the natural frequency calculations as the level of dissipation.
4) *Output from analysis*- The results obtained from the model analysis are magnitude of the frequency and the mode shape.

C. Boundary conditions

For applying various loads to the meshed model the boundary conditions has been applied to the meshed model of the compressor mounting bracket.

1) Material Defining[2]: Material collectors are used for defining the various material properties in the software. "Aluminum" is used with following various properties:
Material is linear and elastic, isotropic and temperature independent.

- Modulus of elasticity E = 6.6 e +04 (N/m2)
- Modulus of rigidity G = 2.7 e +04 (N/mm2)
- Poisson ratio ᴠ = 0.3
- Density ρ = 2.7 e -09 (kg/m3)

2) Defining Property[2]: These collectors contained the properties that are assigned to the components. Card image and material are provided to the component.

- *Card Image* - PSOLID to assign solid elements for 3D meshing
- *Material* - Aluminum (Al) from material collector

3) Rigid body element (RBE): To make rigid regions on the bolts the rigid body elements were used. To represent the studs and bolts line element and RBE elements are used.
RBE2 – Rigid region is created to relates the nodes in the region by generation constraint equations. Two types of nodes are required

Master: A node which represents the fixture is a "master node". This node is an independent node and was created at the fixture mounting position.[2]

Slave: All the other selected nodes are on mounting bracket (at bolt location) represent the "slave nodes".[2]

RBE3 – This is also the rigid region. To represent the mass of the compressor bracket at center the master node is created. Slave nodes are the independent nodes.

4) Load Collectors: Load collectors are used to assign the loads and the constraints to the compressor mounting bracket. Two load collectors are used here as follows:

a) Eigrl (load collector): EIGRL card image defines the data that is needed to perform real Eigen value analysis (vibration or buckling) with the Lanczos Method. EIGRL is used for the calculation of the number of modes and natural frequencies.[2]

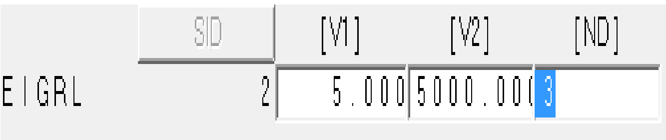
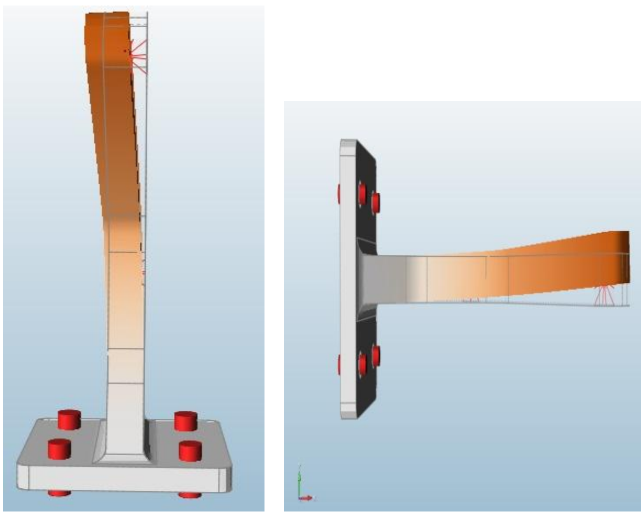
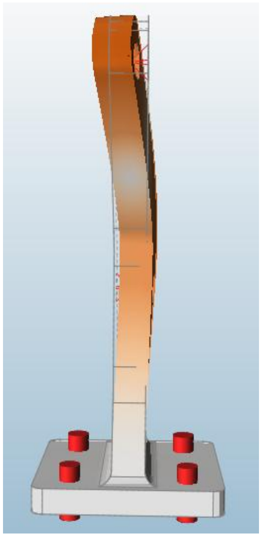


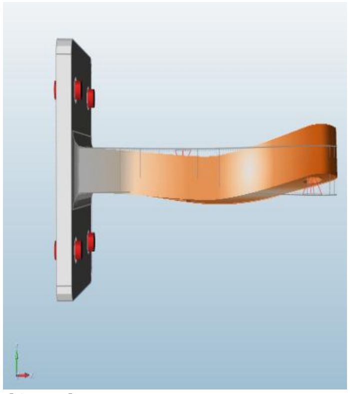
Fig. 4 EIGRL card

b) Constraints (load collector): Node 1 is fixed in all direction in this collector.
Normal modes analysis is done for natural frequencies and mode shapes. Following results are obtained. Fig 4

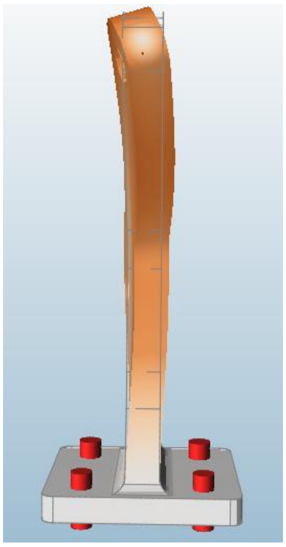


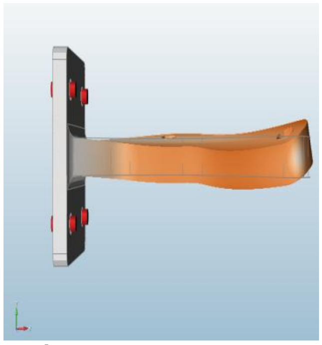
(a) Mode 1





(b) Mode 2





(c) Mode 3

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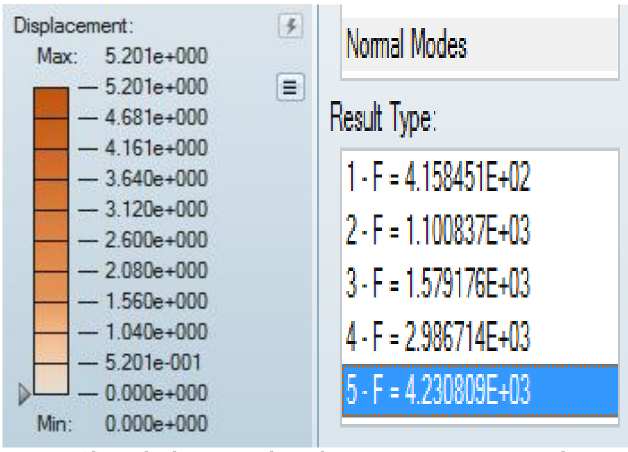


(d) Mode shapes Results and Frequencies at various mode
Fig 5 (a),(b),(c),(d) : Natural frequencies and mode shapes

Normal mode analysis is carried out at the various loading conditions which gave the output of three mode shapes. Various frequencies are obtained at the mode 1, mode 2 and mode 3 respectively.

The obtained frequencies are below the operational vibration frequencies which results in no failure of the compressor mounting bracket.

V. MODAL FREQUENCY RESPONSE ANALYSIS OF AIR CONDITIONER COMPRESSOR MOUNTING BRACKET

External force is given for the harmonic excitation in the modal frequency response analysis of the Air conditioner compressor mounting bracket. This analysis is done along all three axes of the compressor mounting bracket.

A. Modal frequency response analysis of Air Conditioner Compressor mounting bracket along x-axis

In modal frequency response analysis along X direction the forces are applied in the X direction of the bracket and it can move free in this direction. Forces are applied according to industry standards (JIS1601D) for the vibration testing of the automobile air conditioning equipment.[2]

Various load collectors required for the analysis in x direction are:
a) Cons (load collector): Node 1 of the RBE2 is fixed in all the direction except in X direction in this collector.

b) Unit-Load: DAREA load type is used for dynamic loads which represented the constraint load type. It is applied on the RBE2 and node 1 and the acceleration value is 30g.

c) Eigrl Load (Collector): It defines the EIGRL card which defines the value of the frequency range. The compressor mounting bracket is tested along the frequency 50 Hz to 5000Hz.

e) Rload2 (load collector): This load collector is used to give the card which has the initial exaction load for the frequency response analysis of the compressor mounting bracket.
The following parameters are given by editing this collector:[2]
Initial excitation frequency = 415
Increment for the next frequency =1
Number of frequencies = 5

g) Damping Ratio: the ratio of actual damping coefficient to the critical damping coefficient is known as damping ratio. It is a dimensionless measure describing how oscillations in a system decay after a disturbance. Damping ratio is taken as 6% for this analysis.[2]

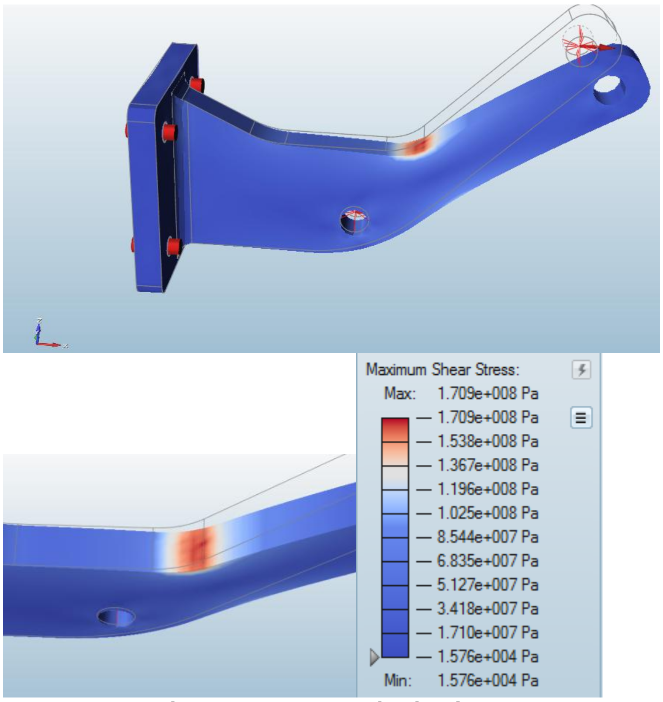


Fig 6. Shear Stress in mounting bracket along x-axis

B. Modal frequency response analysis of Air Conditioner Compressor mounting bracket along Y-axis

Forces are applied in the Y direction in this analysis and compressor mounting bracket is free to move in this direction. All the boundary conditions applied are same as were applied in the X direction except for the first two load collectors.

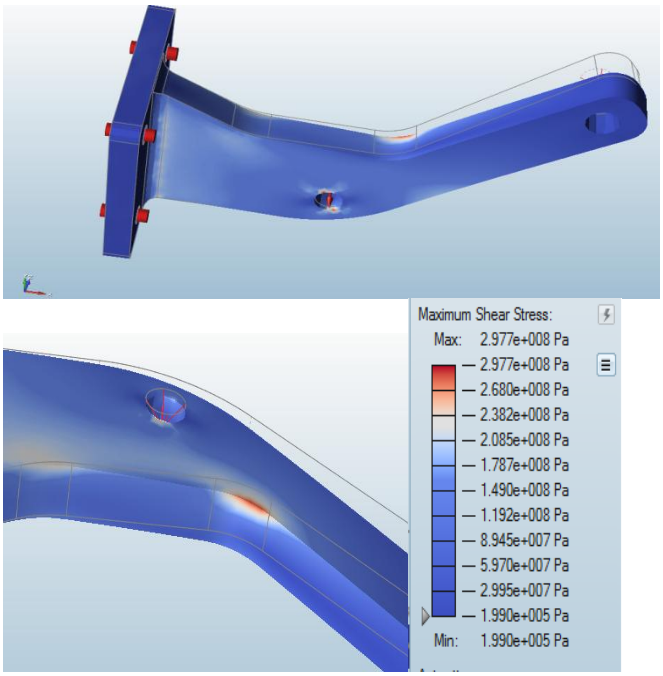
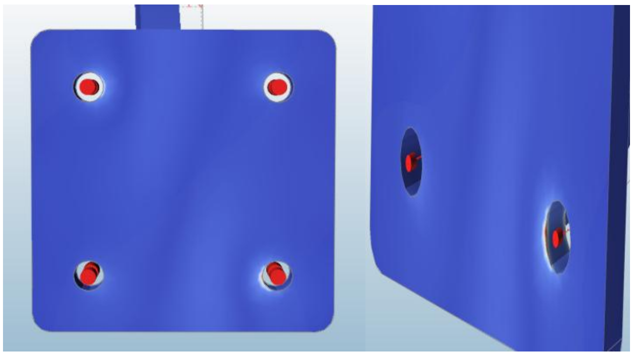


Fig 7 . Shear Stress in mounting bracket along y-axis

C. Modal frequency response analysis of Air Conditioner Compressor mounting bracket along Z-axis

Forces are applied in the Z direction in this analysis and compressor mounting bracket is free to move in this direction.



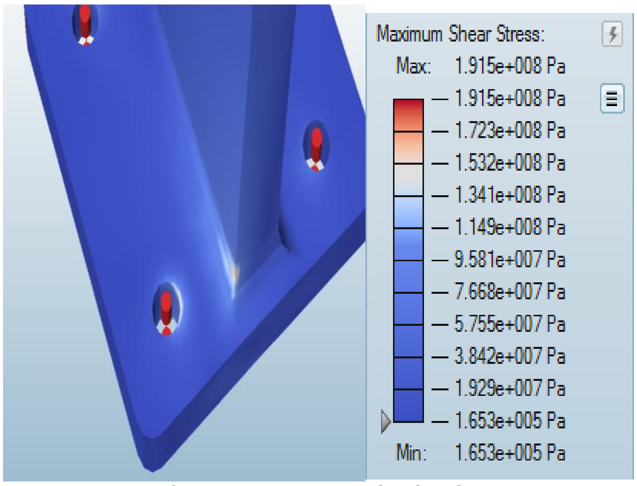


Fig 8. Shear Stress in mounting bracket along z-axis

VI. CONCLUSIONS

(a) Stresses (in MPa) produced in x-axis due to dynamic loading with excitation frequency of 4.158×10^2 are low as compared with the yield strength of the material (300 MPa).
(b) The stresses produced in mounting bracket due to the dynamic load in y-axis with excitation frequency of 1.579×10^3 are low.
(c) The stresses produced in mounting bracket due to the dynamic load in z-axis with excitation frequency of 4.230×10^3 are high as compared to x-axis and y-axis.
(d) Normal mode analysis is carried out at the various loading conditions which gave the output of three mode shapes. 4.158×10^2, 1.579×10^3 and 4.230×10^3 frequencies are obtained at the mode 1, mode 2 and mode 3 respectively
(e) The obtained frequencies are below the operational vibration frequencies which results in no failure of the compressor mounting bracket.

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